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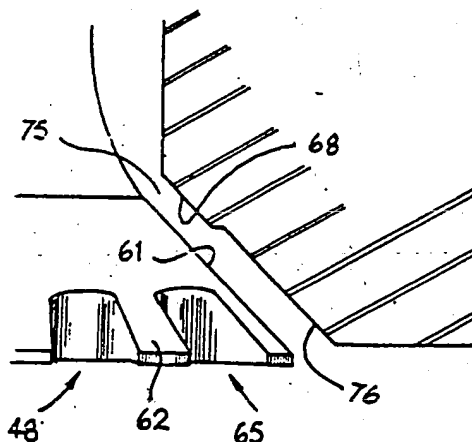
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(54) Title: FUEL INJECTOR NOZZLE



(57) Abstract

A nozzle for the injection of liquid fuel by compressed gas which produces a generally circular first array of gas-entrained fuel droplets and a second array of gas-entrained fuel droplets within the first array. The preferred nozzle has an outwardly opening poppet valve with notches (65) on the perimetral edge of the valve head (48). The division of the fuel-gas charge into two arrays reduces penetration of the charge into the combustion chamber with beneficial effect on combustion efficiency and exhaust emissions. Also disclosed is an arrangement in which an un-notched poppet valve co-operates with a notched valve port to similarly obtain division of the fuel-gas charge into two arrays.

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FUEL INJECTION NOZZLE

This invention relates to a method of injecting a fuel-air mixture into the combustion chamber of an internal combustion engine in a manner to control the fuel distribution within the chamber.

The characteristics of the spray of the fuel droplets issuing
5 from a nozzle into a combustion chamber have major effects on the efficiency of the burning of the fuel which in turn affects the stability of the operation of the engine, the fuel efficiency and the exhaust emissions. To optimise these effects in a spark ignited engine the desirable characteristics of the spray pattern of the fuel issuing
10 from the nozzle include small fuel droplet size, controlled penetration of the fuel spray into the chamber, and at least at low engine loads a relatively contained evenly distributed cloud of fuel droplets.

Some known injection nozzles, used for the delivery of fuel directly into the combustion chamber of an engine, are of the poppet
15 valve type from which the fuel issues in the form of a hollow divergent conical spray, with the fuel droplets forming a continuous wall of the cone extending from the peripheral edge of the poppet valve. The continuous nature of the wall of fuel droplets restricts the extent of atomisation of the fuel, and the dispersion of the fuel droplets in the
20 air to form a fuel mist cloud, which is desirable for ignition and complete combustion of the fuel. Also the continuous wall of fuel droplets, issuing as a continuation of the direction of flow of the droplets from the nozzle, increases the extent of penetration of the fuel into the cylinder which is particularly undesirable under light
25 fuelling conditions.

It is therefore the object of the present invention to provide a method of injecting fuel through a nozzle into a combustion chamber, and a nozzle construction, which will contribute to a reduction in the problems experienced with existing nozzles and to
30 improve emissions control and engine operation stability.

With this object in view there is provided according to one aspect of the present invention a method of injecting fuel into a combustion chamber of an engine comprising entraining the fuel in a gas and selectively injecting the resultant fuel-gas mixture into the
35 combustion chamber, and providing during injection to the combustion

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chamber alternate first and second flow paths for at least part of the fuel-gas mixture so that part of the fuel-gas mixture forms an array of alternate first and second fuel-gas mixture streams issuing into the combustion chamber.

- 5 Preferably the first array of gas entrained fuel droplets issues to form a divergent cone formation and the second array of droplets preferably issues to form a formation which is not divergent, and conveniently issues into a somewhat cylindrical formation or inwardly converging conical formation, disposed within the confines of
10 the outwardly divergent formation of the first array.

More specifically there is provided a method of injecting fuel into a combustion chamber of an engine comprising entraining the fuel in a gas stream and selectively opening a port to inject the fuel-gas mixture so formed into the combustion chamber, and promoting
15 preferred respective paths for the fuel-gas mixture as it passes through the port to produce a first array of generally circular cross-section of gas entrained fuel droplets and a second array of gas entrained fuel droplets within the area defined by the first array issuing from the port.

- 20 In accordance with another aspect of the present invention there is provided a method of injecting fuel into a combustion chamber of an engine comprising entraining the fuel in a gas and selectively opening a port to discharge the fuel-gas mixture so formed into the combustion chamber, and promoting preferred respective paths of gas and
25 fuel as the mixture passes through the open port to produce an array of fuel-gas mixture with alternate regions of differing fuel content around the port.

Preferably the fuel-gas mixture issues with the array of a circular or arcuate cross-section about the axis of the port. The
30 array may be such that alternate regions diverge outwardly about the axis of the port to form a generally conical array and the other regions are in a circular formation about the axis of the port, and are preferably of a converging conical formation.

- The dividing of the fuel-gas charge into two arrays more
35 widely distributes the charge and so reduces the velocity thereof with resultant reduction in the momentum of the fuel droplets and penetration thereof into the combustion chamber. In this regard it is

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desirable for the charge to attain sonic or above sonic velocity at the point of issue from the port in order to promote atomisation. However, high velocities after entry to the combustion chamber are not desirable as they result in deep penetration of the fuel into the combustion chamber. The dividing of the fuel-gas charge as currently proposed assists in permitting sonic velocity of the charge at entry without a correspondingly high penetration fuel spray.

The change in direction of part of the fuel-gas charge to establish the two arrays also reduces the velocity of that part of the fuel-gas charge with respect to the part that does not change direction, thus further reducing fuel penetration. Also it is believed that the change in direction is more readily accommodated by the gas than the fuel droplets, due to the relative densities and resulting momentum effects, and so the inner array is of somewhat lower density.

It is believed that the effect of the hollow spray is that, due to entrainment-induced effects in the gas within the conical array, vortices are produced adjacent the array within the hollow spray of fuel-gas charge issuing from the port. This vortex production effect is particularly effective when the liquid fuel is entrained in a gas as compared with a liquid fuel alone injection system. In the liquid alone injection system there is minimum expansion as the fuel issues through a port and so any vortex production effects only extend to the gas in the combustion chamber within the area immediate to the spray.

In contrast in the present proposal, where the liquid fuel is entrained in gas, the substantial pressure drop through the port will result in a substantial expansion of the gas issuing into the combustion chamber with the fuel. The vortex production effect is thus more widely spread and the liquid fuel droplets carried in the gas are similarly spread. The above reference to the wide spread of the vortex production effect refers to a spread within the ambit of the fuel spray issuing from the port and not to substantial spread throughout the whole combustion chamber.

The overall effect of entraining the fuel in a gas and injecting the fuel-gas charge so created into the combustion chamber in the form of two concentric arrays of fuel droplet streams, is to

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limit the extent of penetration of the fuel into the chamber, and to provide a confined fuel cloud, with fuel distributed therethroughout, at the injection point.

When the arrays are such that the streams of fuel droplets are in a circular or conical formation, a toroidal air flow is created within the formation generally concentric therewith. The air flow in the outer region of the toroid compliments that of the fuel droplets issuing from the port, and fuel becomes entrained in the toroidal air flow to be carried inward of the formation. This dispersion of the fuel droplets contributes to the distribution of the fuel while retaining it within a defined area.

In accordance with another aspect of the present invention there is provided a method of injecting fuel into a combustion chamber of an engine comprising entraining the fuel in a gas and selectively opening a port to inject the resultant fuel-gas mixture into the combustion chamber, and promoting preferred respective paths of gas and fuel as the mixture passes through the open port to produce an array of alternate areas of fuel rich and fuel lean mixtures around the port.

More specifically there is provided in a fuel injection system for an internal combustion engine where fuel entrained in gas is injected into an engine combustion chamber, a selectively openable nozzle means through which the fuel-gas mixture is delivered to the combustion chamber and incorporating a flow divider means, in the path of the mixture issuing from the nozzle means when open, to form a first array of generally circular cross-section of gas entrained fuel droplets and a second array of gas entrained fuel droplets within the area defined by the first array.

Another aspect of the present invention provides, in a fuel injection system where fuel entrained in gas is injected into a combustion chamber, a selectively openable nozzle means through which the fuel-gas mixture is injected into the combustion chamber, said nozzle means being adapted to produce an array of alternate zones of differing fuel content fuel-gas mixtures issuing therefrom when the nozzle means is open.

Conveniently the nozzle means includes means located in the path of the fuel-gas mixture, when the nozzle is open, and adapted to divide the flow of the fuel-gas mixture into zones of differing fuel

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content. Preferably the nozzle means is in the form of a poppet valve having a movable valve element co-operating with a port to provide a seal area therebetween when the nozzle is closed, with the divider means downstream of the seal area. The divider means may be integral
5 with the port or the valve element or respective co-operating portions of the flow director may be integral with each.

Preferably the movable valve element of the poppet valve is provided with a plurality of notches spaced around the periphery of the terminal edge portion. The provision of these notches provides two
10 alternative sets of paths for the fuel-gas mixture, an outer set formed by the un-notched portions of the terminal edge of the valve element, and the other set passing through the notches to be thereby displaced radially inward from the terminal edge of the valve element.

The surface of the valve element over which the fuel-gas
15 mixture passes when the nozzle is open is preferably of a divergent conical form so that the fuel-gas mixture issuing from the terminal edge will initially maintain this direction of flow to form an outer array of gas entrained fuel droplets. However where the terminal edge is interrupted by the notches the fuel and gas presented to the notch
20 will flow therethrough to issue from the nozzle inwardly of the terminal edge.

The wall attachment effect present when a fluid is flowing along a surface is believed to also contribute to the nature of the flow of the gas and fuel mixture through the notches.

25 It is believed that the gas is more susceptible to the wall attachment effect than the fuel and, together with the effects of the surface tension of the fuel, result in some shedding of fuel from the fuel-gas mixture at the edge of the notch which is first encountered by the mixture passing over the valve element. The shedded fuel is
30 directed to flow around, rather than through, the notch and so becomes entrained in and enriches the fuel-gas mixture flowing down the un-notched areas of the valve element. The momentum effects on the fuel may also contribute to some shedding of fuel from the gas diverted through the notches.

35 This breaking up of the fuel-gas mixture into a plurality of arrays of fuel droplet streams provides a greater access for the fuel droplets to mix with the gas, and the additional edge length derived by

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the provision of notches increases the effect of shearing on the fuel droplets to achieve greater atomisation of the fuel.

The streams of fuel-gas mixture issuing from the terminal edge of the valve element in a conical formation establishes a toroidal like vortex flow within the confines of the conical formation. The direction of this toroidal vortex flow is such that the radial outer part thereof, adjacent the fuel-gas streams in the conical formation, is moving in the same direction as those streams. This flow picks up fuel droplets from the streams and carries them inwardly of the conical formation. The result is that the fuel-gas streams are further broken up to increase distribution of the fuel, and to form a contained fuel mist cloud extending across the full extent of the conical formation initiated by the fuel-gas stream issuing from the valve element. The breaking up and drawing inwardly of the fuel-gas mixture also limits the depth of penetration of the fuel into the combustion chamber and so may retain a rich mixture in the area of a spark plug in the region of the fuel injector for ready ignition, and limits dispersion of fuel into remote areas of the combustion chamber.

The fuel-gas cloud contains a constrained mass of fuel droplets finely dispersed and mixed with sufficient air to provide a readily ignitable fuel charge.

The invention will be more readily understood from the following description of a practical arrangement of apparatus for delivering fuel to an engine and several constructions of the valve control nozzles through which a fuel-air mixture is delivered to the combustion chamber of an engine.

In the drawings:-

Figure 1 is a longitudinal sectional view of a two stroke cycle engine to which the presently proposed fuel injection method and apparatus is applied.

Figure 2 is an elevational view partly in section of a fuel metering and injection device for which the present invention is applicable. It is shown diagrammatically coupled to its associated fuel and air supply.

Figures 3 and 4 are end and side elevational views of one form of valve head embodying the present invention.

Figures 5 and 6 are end and side elevational views of another

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form of valve head embodying the present invention.

Figure 7 is a sectional view to a large scale of part of the valve similar to that shown in Figures 5 and 6 and a complementary port and valve seat.

5 Figure 8 is a perspective view of a valve port incorporating a further form of the present invention.

Figure 9 illustrates the fuel cloud formation achieved with the valve head shape shown in Figures 5 to 6.

Figure 10 is a sectional view through the fuel cloud shown in
10 Figure 9 illustrating flow patterns in the fuel cloud.

Figure 11 is a graph showing a comparison of the HC content of the exhaust gas from engines operating with a plain poppet valve and the same engine with a notched poppet valve.

Referring now to Figure 1 the engine 9 is a single cylinder
15 two-stroke cycle engine, of generally conventional construction, having a cylinder 10, crankcase 11 and piston 12 that reciprocates in the cylinder 10. The piston 12 is coupled by the connecting rod 13 to the crankshaft 14. The crankcase is provided with air induction ports 15, incorporating conventional reed valves 19 and three transfer passages
20 16 (only one shown) communicate the crankcase with respective transfer ports, two of which are shown at 17 and 18, the third being the equivalent to 17 on the opposite side of port 18.

The transfer ports are each formed in the wall of the cylinder 10 normally with their respective upper edge located in the
25 same diametral plane of the cylinder. An exhaust port 20 is formed in the wall of the cylinder generally opposite the central transfer port 18. The upper edge of the exhaust port is slightly above the diametral plane of the transfer ports upper edges, and will accordingly close later in the engine cycle.

30 The detachable cylinder head 21 has a combustion cavity 22 into which the spark plug 23 and fuel injector nozzle 24 project. The cavity 22 is located substantially symmetrical with respect to the axial plane of the cylinder extending through the centre of the transfer port 18 and exhaust port 20. The cavity 22 extends across the
35 cylinder from the cylinder wall immediately above the transfer port 18 to a distance past the cylinder centre line.

The cross sectional shape of the cavity 22 along the above

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referred to axial plane of the cylinder is substantially arcuate at the deepest point or base 28, with the centre line of the arc somewhat closer to the centre line of the cylinder than to the cylinder wall above the transfer port 18. The end of the arcuate base 28 closer to the cylinder wall above the transfer port 18, merges with a generally straight face 25 extending to the underface 29 of the cylinder head 21 at the cylinder wall. The face 25 is inclined upwardly from the cylinder wall to the arcuate base 28 of the cavity.

The opposite or inner end of the arcuate base 28 merges with a relatively short steep face 26 that extends to the underface 29 of the cylinder head. The face 26 also meets the underface 29 at a relatively steep angle. The opposite side walls of the cavity (one only being shown at 27) are generally flat and parallel to the above referred to axial plane of the cylinder, and so also meet the underface 29 of the cylinder head at a steep angle.

The injector nozzle 24 is located at the deepest part of the cavity 22, while the spark plug 23, is located in the face of the cavity remote from the transfer port 18. Accordingly, the air charge entering the cylinder will pass along the cavity past the injector nozzle 24 toward the spark plug and so carries the fuel from the nozzle to the spark plug.

Further details of the form of the cavity 22 and of the combustion process derived therefrom are disclosed in British Patent Application No.8612607 lodged on the 23rd May, 1986 corresponding United States Patent Application lodged on the 26th May, 1986 entitled "Improvements Relating to Two Stroke Cycle Internal Combustion Engines", by Schlunke and Davis, the disclosure of each being hereby incorporated herein by this in reference.

The injector nozzle 24 is an integral part of a fuel metering and injection system whereby fuel entrained in air is delivered to the combustion chamber of the engine by the pressure of the air supply. One particular form of fuel metering and injection unit is illustrated in Figure 2 of the drawings.

The fuel metering and injection unit incorporates a suitably available metering device 30, such as an automotive type throttle body injector, coupled to an injector body 31 having a holding chamber 32 therein. Fuel is drawn from the fuel reservoir 35 delivered by the

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fuel pump 36 via the pressure regulator 37 through fuel inlet port 33 to the metering device 30. The metering device operating in a known manner meters an amount of fuel into the holding chamber 32 in accordance with the engine fuel demand. Excess fuel supplied to the
5 metering device is returned to the fuel reservoir 35 via the fuel return port 34. The particular construction of the fuel metering device 30 is not critical to the present invention and any suitable device may be used.

In operation, the holding chamber 32 is pressurised by air
10 supplied from the air source 38 via pressure regular 39 through air inlet port 45 in the body 31. Injection valve 43 is actuated to permit the pressurised air to discharge the metered amount of fuel through injector tip 42 into a combustion chamber of the engine. Injection valve 43 is of the poppet valve construction opening inwardly to the
15 combustion chamber, that is, outwardly from the holding chamber.

The injection valve 43 is coupled, via a valve stem 44, which passes through the holding chamber 32, to the armature 41 of solenoid 47 located within the injector body 31. The valve 43 is biased to the closed position by the disc spring 40, and is opened by energising the
20 solenoid 47. Energising of the solenoid 47 is controlled in timed relation to the engine cycle to effect delivery of the fuel from the holding chamber 32 to the engine combustion chamber.

Further details of the operation of the fuel injection system incorporating a holding chamber is disclosed in Australian Patent
25 Applications Nos. 32132/84 and 46758/85 and respective corresponding United States Patent Applications No. 740067 filed 2nd April 1985, and No. 849501 by M. McKay, the disclosures of which are incorporated herein by reference.

Preferred forms of the head portion of the injection valve 43
30 are shown in Figures 3 to 6 which depict two views of two alternative forms of valve head intended to be used with a basically conventional valve seat. As seen in each of Figures 3 and 5, there are twelve equally spaced notches or slots 65 about the periphery of the head 48 of the valve, and an annular sealing face 61, which in use co-operates
35 with a corresponding sealing face on a co-operating valve seat as indicated at 68 in Figure 7. The included angle of the sealing face in these preferred forms is 120° but may be at any other appropriate angle

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such as, for example, the sometimes used 90° angle. In the embodiments shown the annular portion 62 of the valve head, in which the notches are provided, has the same included angle of taper as the sealing face 61, however this is not essential. For example, if the included angle 5 of the sealing face is 90° the angle of the annular portion 62 may be 120° .

In each of the embodiments shown the twelve notches 65 are equally spaced around the perimeter of the head, and the opposite walls 66 are radial and have an included angle therebetween of 15° . In the 10 specific valves shown in the drawings the overall diameter of the valve head is 4.7 millimetres while the width of the notch at the periphery is 0.7 millimetres and a total notch depth on the centre line of the notch and in the direction radial to the head is 0.7 millimetres.

The width of notches may vary to suit particular performance 15 requirements and preferably the notches occupy 35 to 65% of the length of the edge in which they are located. Usually the notches occupy 40 to 60% of said edge length.

In the embodiment shown in Figures 3 and 4 the base 67 of each notch is parallel to the axis of the valve.

20 In alternative constructions the base of the notch may be of a configuration other than parallel to the axis of the valve, and typically may be inclined downwardly and inwardly towards the axis of the valve as at 167 in Figure 6. In this embodiment the angle of the inclined base to the axis of the valve is 30° . In other variations 25 (not shown) the base of the notch is curved in the direction from the top to the bottom of the valve head rather than flat.

Further, in the embodiments shown the opposite side walls 66 of the notches are in radial planes parallel to the axis of the valve, however, the notches may be arranged so that the side walls thereof are 30 in planes inclined to the valve axis, and typically the inclination may be of order of 30° .

It is understood that the base 67, 167 of the notch in the above referred to embodiments need not be straight in the plane of the notch as shown in Figures 4 and 6 but may be of an arcuate form 35 blending smoothly with the opposite side walls 66 of the notch. Also the shape of the land 69 between respective notches may be of generally semi-circular cross section rather than of an arcuate form as shown in

Figures 4 and 5 corresponding to the peripheral contour of the valve.

Figures 7 of the drawings shows in part a poppet type valve, as above described, and the co-operating part of a port. The sealing face 68 of the port co-operates with the sealing face 61 of the valve head 48 when the valve is in the closed position. An annular passage 75 is formed between these sealing faces when the valve is open (as shown) through which the fuel-air mixture flows to be delivered into the combustion chamber.

The recessed face 76 of the port, downstream from the sealing face 68, has a clearance with respect to the notched portion 62 of the valve head 48. This clearance reduces the risk of the defective sealing of the valve as a result of carbon particles or other foreign matter on the face 76. Also as the valve does not contact the face 76 when closed, carbon particles initially deposited thereon are likely to be swept off by the fuel-air charge passing when the valve is open.

The Notches in the periphery of the valve head divide the air entrained fuel flow into respective paths, that which passes over the normal peripheral edge of the valve, and that which passes through the notches. These respective flow paths in effect form the concentric arrays of air entrained fuel droplets and are depicted in Figures 9 at 71 and 70. The streams issuing from the un-notched portion of the valve edged may be somewhat richer in fuel than the streams 71, as previously discussed. It will also be appreciated that the provision of the notches increases the flow path area for the gas and fuel and so reduces their velocity and thus the extent of penetration into the combustion chamber. Also the effective functioning of this valve is less dependent on smooth surfaces and uninterrupted flow, and so carbon built up on the valve and port surfaces are not a major problem.

Figure 9 depicts the external appearance of the two arrays of fuel streams 70 and 71 and the resulting fuel cloud 72, and show that as streams move some distance from the nozzle and hence decelerate, the streams break up into a fuel mist. This mist is carried inwardly from the boundary array to form within the general confine of the streams a generally continuous cloud of fine droplets of fuel dispersed within a body of air.

Figure 10 is a sectional view which illustrates the basic flows associated with the formation of the fuel cloud 72. It will be

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noted that the streams 70 of air and fuel issue from the edge of the poppet valve on a divergent path, and so provide a pressure gradient below the valve head 48, which develops a generally toroidal air flow 73 within the volume bounded by the fuel-air streams 70. The path of the toroidal flow adjacent the streams 70 is in the same direction thereas, and the outer portion of the toroidal air flow will take up fuel droplets from the streams 70 and 71 and carry them inwardly to be dispersed within the air moving in the toroidal flow, which assists in breaking up and slowing down the air-fuel streams 70 and 71. Thus the effect of this toroidal air flow 73 is to generally prevent outward dispersion of the fuel droplets which would cause a relatively dispersed fuel cloud, and to carry the fuel drops towards the centre so that a concentrated fuel cloud 72 is established.

Although the preferred form of the invention has a series of notches in the perimetral area of the poppet valve head, beneficial results are also achieved with a series of notches in the port together with a conventional poppet valve without notches. A typical configuration of a notched port is shown in Figure 8.

The port has an annular sealing face 80 which in use co-operates with a corresponding sealing face on a poppet valve. Downstream of the sealing face 80 is an annular end face 81 generally normal to the port axis, and an interconnecting generally cylindrical internal face 84. Twelve equally spaced notches 82 are formed in the end face 81 extending from the internal face 84 to the external peripheral face 83. Preferably the opposite walls 85 of the notches are parallel. The base of the notches is preferably flat, and parallel to the end face 81. The depth of the notch is such that that part of the fuel-air charge travelling through the port towards the notch when the valve is open, will not impinge on the cylindrical surface 84 and will pass through the notch unimpeded. The part of the fuel-air charge that does impinge on the cylindrical surface 84 between the notches 82 is deflected to travel along that face.

The above described arrangement of notches in the port will divide the fuel-air mixture issuing from the port into two arrays of fuel droplets, an outer array issuing through the notches 82 and an inner array issuing from the un-notched portions of the internal face 81. In this arrangement the outer array is divergent with respect to

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the axis of the port generally continuing in the direction of the sealing face 80 while the inner array is generally of a cylindrical form following the internal face 81.

5 The fuel cloud created by the notched port is more widely dispersed than the that resulting from a notched valve head of the same angle. It is also less penetrating, so the resultant fuel cloud may be principally retained within a combustion cavity provided in the cylinder head such as the cavity 22 in Figure 1. Also when using the above notched port configuration the two arrays of fuel droplets
10 provide an increased exposure of the fuel to air to promote ignitability and combustibility.

Figure 11 contains plots of hydrocarbon content in the exhaust gas obtained from operating the same engine with a conventional poppet valve in the injector and with a notched poppet valve similar to
15 that shown in Figures 3 and 4.

The solid line indicates the hydrocarbon content of the exhaust gas with the conventional poppet valve and the broken line hydrocarbons with the notched poppet valve. The engine used in this test was intended for automobile use where the majority of operation is
20 in the low to medium power range, and this is the operating range where the notched poppet valve provided the higher rate of reduction of hydrocarbon in the exhaust gas. The notched poppet also contributes to a reduction in NOx in the exhaust, but to a lesser extent than the effect on hydrocarbons. The notched poppet is thus a development that
25 contributes significantly to the control of emissions in the exhaust of internal combustion engines, particularly automobile type engines.

It is to be understood that the present invention may be applied to any form of fuel injection system wherein the fuel is entrained in air or another gas, particularly a combustion supporting
30 gas, and is delivered into a combustion chamber through a nozzle.

In one particular fuel injection system a metered quantity of fuel is delivered into a body of air and the so formed fuel and air mixture is discharged through a nozzle to the engine combustion chamber, upon opening of the nozzle by the pressure differential
35 existing between the body of air and the combustion chamber. The body of air may be static or moving as the fuel is metered thereinto. The mode of metering the fuel may be of any suitable type including

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pressurised fuel supplies that issue for an adjustable time period into the air body, or individual measured quantities of fuel delivered, such as by a pulse of air, into the body of air.

Fuel injection systems and metering devices suitable for use
5 in carrying the present invention into practice are disclosed in our
U.S.A. Patents Nos. 4,462,760, 4,554,945, Australian Patent
Applications Nos. 32132/84 and 46758/85, British Patent Application
No. 8612600 and the corresponding United States Patent Applications,
the disclosures in each being herewith incorporated in this
10 specification by reference.

In the present specification specific reference has been made
to the use of the present invention in conjunction with an engine
operating on the two-stroke cycle and with spark ignition, however it
is to be understood that the invention is equally applicable to spark
15 ignited engines operating on the four stroke cycle. The invention is
applicable to internal combustion engines for all uses but is
particularly useful in contributing to fuel economy and control of
exhaust emissions in engines for or in vehicles, including automobiles,
motor cycles and boats including outboard marine engines.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of injecting fuel into a combustion chamber of an engine comprising entraining fuel in a gas and selectively injecting the resultant fuel-gas mixture into the combustion chamber, and providing during injection to the combustion chamber alternate first and second flow paths for at least part of the fuel-gas mixture so said part of the fuel-gas mixture forms an array of alternate first and second fuel-gas mixture streams issuing into the combustion chamber.
2. A method as claimed in claim 1 wherein the array is of generally arcuate cross-section
3. A method of injecting fuel into a combustion chamber of an engine comprising entraining the fuel in a gas stream and selectively opening a port to inject the fuel-gas mixture so formed into the combustion chamber, and promoting preferred respective paths for the fuel-gas mixture as it passes through the port to produce a first array of generally circular cross-section of gas entrained fuel droplets and a second array of gas entrained fuel droplets within the region defined by the first array issuing from the port.
4. A method as claimed in claim 3 wherein the first array of gas entrained fuel droplets diverge outwardly with respect to the axis of the array.
5. A method as claimed in claim 1 or 2 wherein the first array of gas entrained fuel droplets diverge outwardly with respect of the second array.
6. A method as claimed in claim 3 or 4 wherein the second array of gas entrained fuel droplets converge inwardly with respect to the axis of the array.

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7. A method as claimed in any one of claims 3, to 6 wherein during formation of the first and second array fuel is shed from the gas forming the second array and taken up by the gas forming the first array so that the fuel content of the fuel-gas mixture in the first array is greater than in the second array.
8. A method as claimed in claim 1, 2 or 3 wherein the gas entrained fuel is injected to the combustion chamber through a port and a valve element is selectively movable relative to the port to open and close the port, said port and valve element defining an annular passage when the port is open, said passage having a series of notches along at least part of at least one of the peripheral edges of said annular passage, said gas entrained fuel being propelled through said passage and with part passing through said notches, said notches being arranged to form an array of gas entrained fuel droplets issuing into the combustion chamber on a path different to that of the remainder of the gas entrained fuel droplets issuing from the annular passage.
9. A method of injecting fuel into a combustion chamber of an engine comprising entraining the fuel in a gas and selectively opening a port to inject the resultant fuel-gas mixture into the combustion chamber, and promoting preferred respective paths of gas and fuel as the mixture passes through the open port to produce an array of alternate areas of fuel rich and fuel lean mixtures around the port.
10. In a fuel injection system for internal combustion engines where fuel entrained in gas is injected into a combustion chamber as a fuel-gas mixture, means providing alternate first and second flow paths for at least part of the fuel-gas mixture when being injected to the combustion chamber, said means being adapted so that the fuel-gas mixture following said alternate paths will form an array of alternative first and second fuel-gas streams to issue into the combustion chamber.

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11. The combination claimed in claim 10 wherein the means providing said alternate paths is arranged so said array is of generally arcuate or circular cross-section.
12. The combination as claimed in claim 10 wherein said alternate paths provided by said means are arranged so that adjacent first and second streams will diverge as they issue into the combustion chamber.
13. The combination as claimed in claim 10 or 12 wherein said means is adapted so that said alternate paths are located in a generally circular or arcuate formation about an axis, and said first fuel-gas streams diverge outwardly with respect to said axis.
14. The combination as claimed in claim 13 wherein said means is adapted so said second fuel-gas streams converge inwardly with respect to said axis.
15. In a fuel injection system for an internal combustion engine, where fuel entrained in gas is injected into a combustion chamber, nozzle means incorporating an openable nozzle through which the fuel and gas mixture is delivered to the combustion chamber and flow divider means in the path of the mixture issuing through the nozzle when open, to form a first array of generally circular cross-section of gas entrained fuel droplets and a second array of gas entrained fuel droplets within the area defined by the first array.
16. The combination as claimed in claim 15 wherein said flow divider means is adapted so that the first array of fuel droplets diverges outwardly with respect to the axis of the array.
17. The combination as claimed in claim 15 or 16 wherein said flow divider means is adapted so that the second array of fuel droplets is generally cylindrical.

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18. In a fuel injection system for an internal combustion engine, where fuel entrained in gas is delivered to the engine combustion chamber through nozzle means as a fuel-gas mixture said nozzle means including a port through which the fuel-gas mixture issues into the combustion chamber, a valve element operable to selectively open and close said port, said valve element and port having respective portions defining therebetween when the port is open a passage from which the fuel-gas mixture will issue into the combustion chamber, one of said portions incorporating flow divider means providing a plurality of alternate first and second flow paths for at least part of the fuel-gas mixture passing through said passage, whereby the fuel-gas mixture following said alternate paths will form an array of alternate first and second fuel-gas streams issuing into said combustion chamber.
19. The combination as claimed in claim 18 wherein said flow divider means comprises discontinuities in said one portion at that edge from which the mixture issues, whereby the fuel-gas mixture passing through the discontinuities will be deflected from the trajectory of the remainder of the fuel-gas mixture such that it is deflected inwardly with respect to the mixture passing the remainder of said edge.
20. The combination as claimed in claim 18 wherein said flow divider means comprises discontinuities in said one portion of that edge from which the mixture issues, whereby the fuel-gas mixture not passing through the discontinuities will be deflected from the trajectory of the remainder of the fuel-gas mixture such that it is deflected inwardly with respect to the mixture passing the remainder of said edge.
21. The combination as claimed in claim 19 wherein said discontinuities comprise a plurality of spaced notches in said valve element.
22. The combination as claimed in claim 21 valve element is a poppet valve opening inwardly to said combustion chamber.

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23. The combination as claimed in claim 18 wherein the passage is an annular passage and the flow divider means comprise discontinuities spaced equally along one perimetral edge of said one portion.
24. In a fuel injection system for an internal combustion engine wherein fuel entrained in gas is delivered to a combustion chamber through nozzle means as a fuel-gas mixture, said nozzle means comprising a port through which the fuel-gas mixture passes to the combustion chamber, a valve element operable to selectively open and close said port, the valve element and port having respective annular surfaces which define, when the port is open, an annular passage through which the fuel-gas mixture passes to the combustion chamber, one of said surfaces having a terminal edge portion at the downstream end thereof, and a plurality of notches in said edge portion arranged so that part of the fuel-gas mixture will issue from the passage into the combustion chamber through said notches.
25. The combination as claimed in claim 24 wherein the port and valve element are each of a circular cross-section and have respective annular sealing faces which close the port when in mutual engagement, said valve element being displaceable relative to the port in the direction towards the combustion chamber to effect opening of the port.
26. The combination as claimed in claim 24 or 25 wherein the notches are provided in the terminal edge portion of the valve element.
27. The combination as claimed in claim 26 wherein the notches are equally spaced around the periphery of the terminal edge portion of the valve element.
28. The combination as claimed in claim 19 wherein the discontinuities are formed in the portion of the valve element defining said passage.

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29. The combination as claimed in claim 28 wherein the discontinuities comprise a plurality of peripherally spaced notches in said edge of the valve element.
30. The combination as claimed in any one of claims 26 to 29 wherein each notch has opposite side walls extending inwardly from the periphery of the terminal edge portion, said side walls being in respective planes parallel to the valve element axis.
31. The combination as claimed in any one of claims 26 to 29 wherein each notch has opposite side walls in planes radial to the valve element axis.
32. The combination as claimed in anyone of claims 26 to 29 wherein each notch has opposite side walls in respective planes inclined to the valve element axis.
33. The combination as claimed in any one of claims 30 to 32 wherein each notch has a base wall extending between the side wall said base wall being in a plane inclined inwardly toward the valve element axis.
34. The combination as claimed in claim 33 wherein said plane of the base wall is inclined at 30° to the valve element axis.
35. For use in a fuel injection system of an internal combustion engine as claimed in any one of claims 24 to 32, a valve element having a valve head with a generally conical peripheral surface with a terminal edge at the larger end thereof, said peripheral surface having an annular sealing surface to co-operate in use with the port to form a seal therewith, and a plurality of notches in said peripheral surface between said annular sealing surface and the terminal edge, said notches being spaced peripherally about the valve head and extending through said terminal edge.

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36. The combination as claimed in claim 24 or 25 wherein the notches are provided in the terminal edge portion of the port.
37. The combination as claimed in claim 36 wherein said terminal edge portion presents an internal cylindrical or conical wall and the notches extending outwardly through said wall with respect to the axis of thereof.
38. The combination as claimed in claim 36 or 37 wherein the notches are spaced equally about the periphery of the wall.
39. For use in a fuel injection system of an internal combustion engine as claimed in claim 24, 25, 36, 37 and 38 a port seat unit having an annular sealing surface to co-operate in use with the valve element to form a seal therewith, and an annular wall portion extending from said sealing surface to form a terminal edge, said annular wall portion having a plurality of peripherally spaced notches extending through the annular wall portion from said terminal edge toward said sealing surface.
40. The combination as claimed in any one of claims 21, 22, 24 to 27 and 30 to 39 wherein the notches occupy between 35% and 65% of the length of said edge.
41. The combination as claimed in claim 40 wherein the notches occupy between 40% to 60% of the length of said edge.
42. An automobile internal combustion engine including a fuel injection system operable in accordance with the method defined in any one of claims 1 to 9.
43. In a road transport vehicle an internal combustion engine including a fuel injection system operable in accordance with the method defined in any one of claims 1 to 9.

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44. An outboard marine internal combustion engine including a fuel injection system operable in accordance with the method defined in any one of claims 1 to 9.
45. An automobile internal combustion engine including a fuel injection system as claimed in any one of claims 10 to 34 and 36 to 38.
46. In a road transport vehicle an internal combustion engine including a fuel injection system as claimed in any one of claims 10 to 34 and 36 to 38.
47. An outboard marine internal combustion engine including a fuel injection system as claimed in any one of claims 10 to 34 and 36 to 38.
48. An injection nozzle port for a fuel injector for an internal combustion engine, said nozzle being as herein described with particular reference to Figure 8.
49. A poppet valve head for an injector nozzle for a fuel injection for an internal combustion engine, said valve being as herein described with particular reference to Figures 3 to 8.

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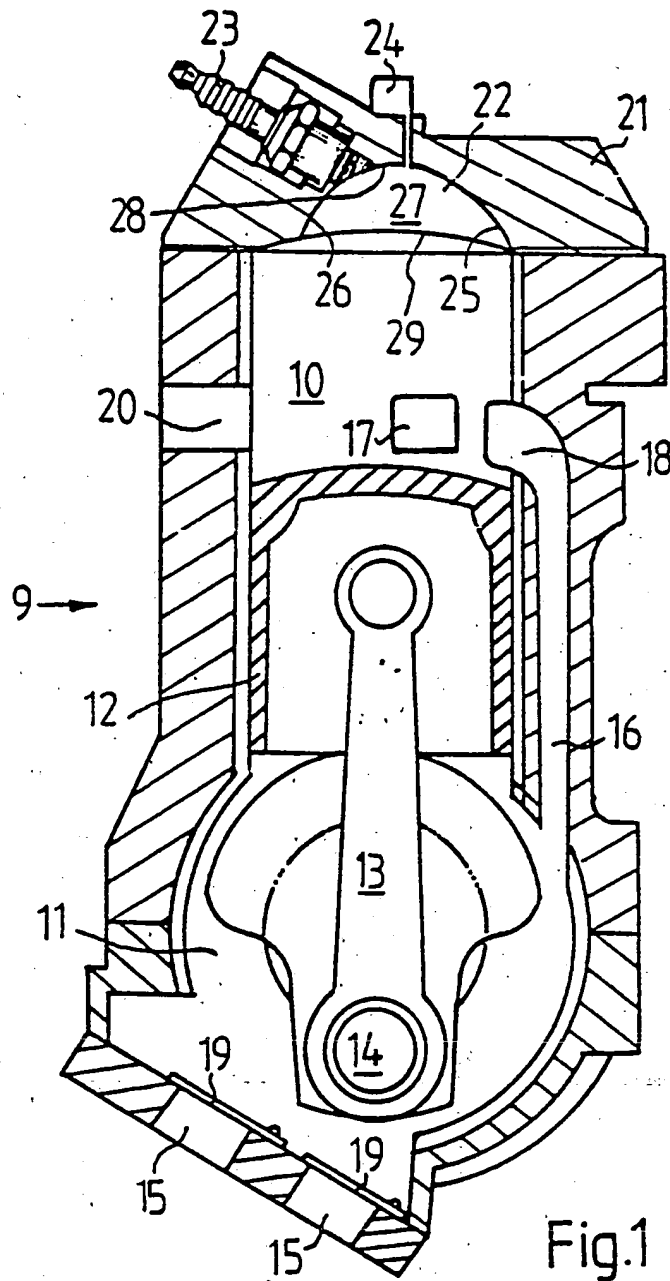
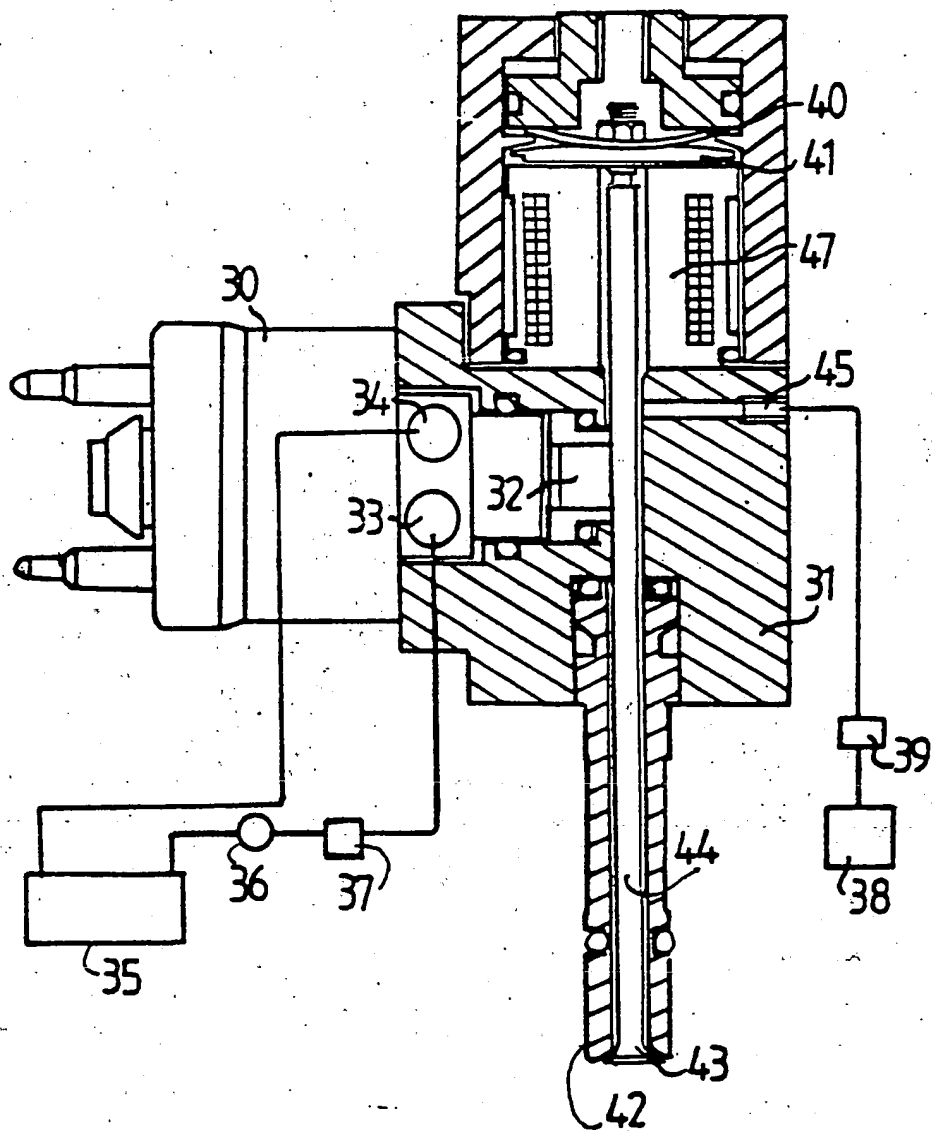


Fig.1

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FIG. 2.



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FIG. 3.

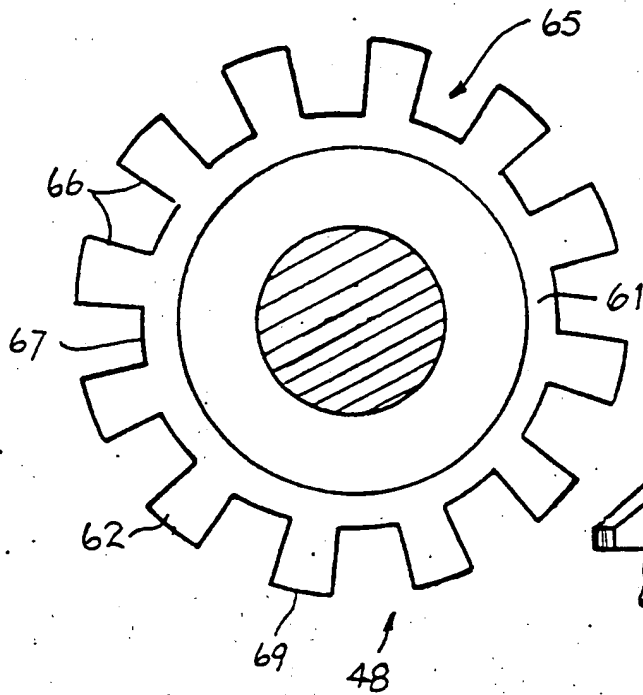


FIG. 4.

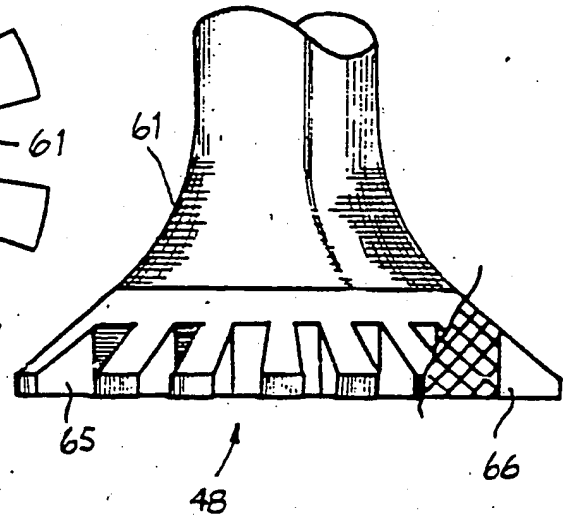


FIG. 5.

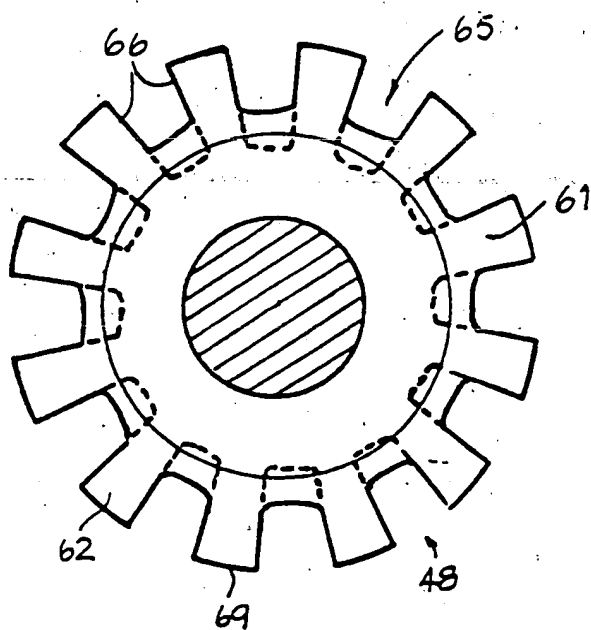
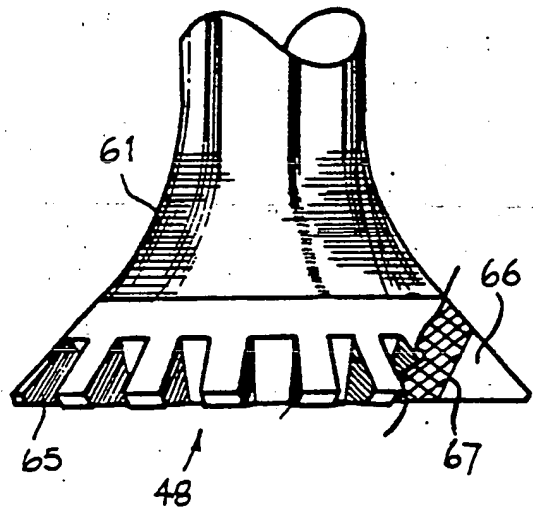


FIG. 6.



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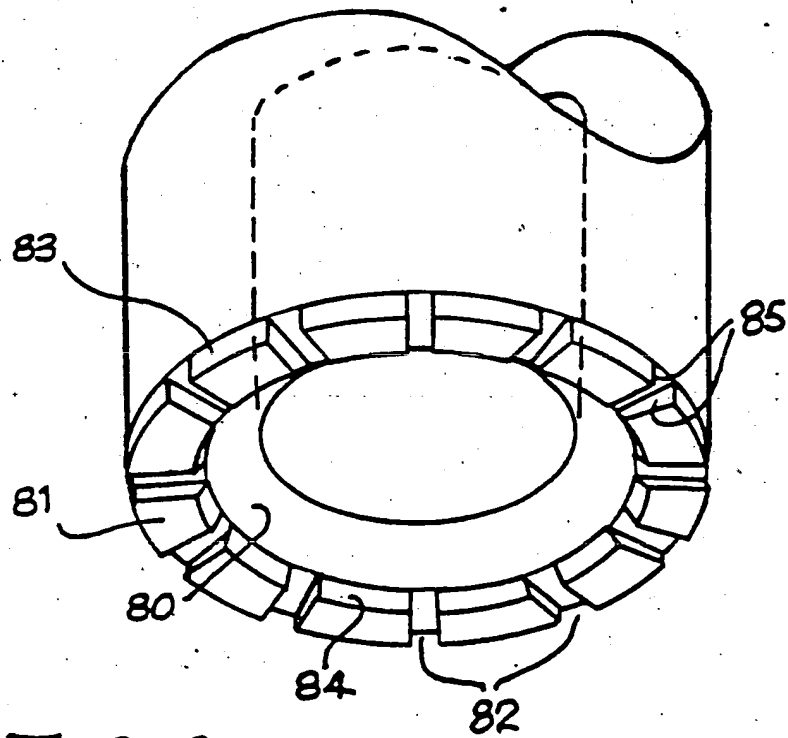
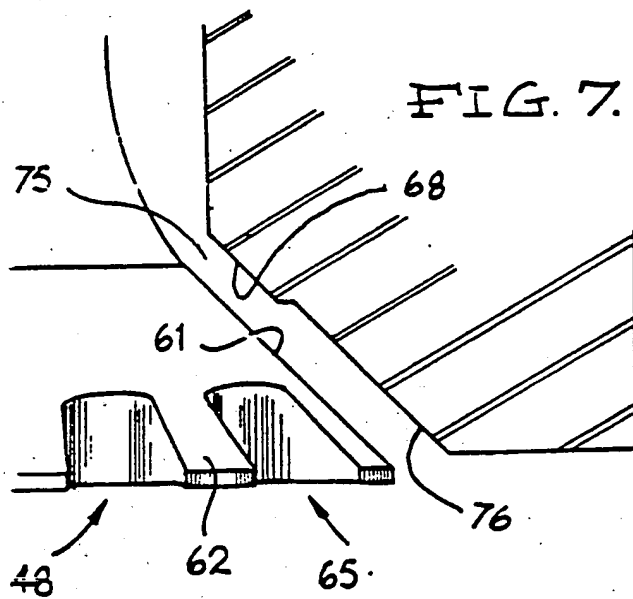
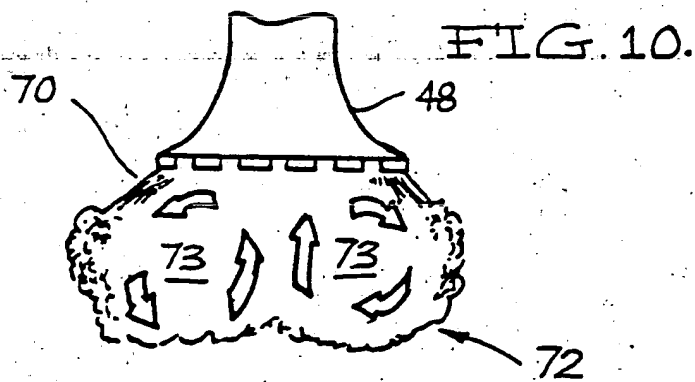
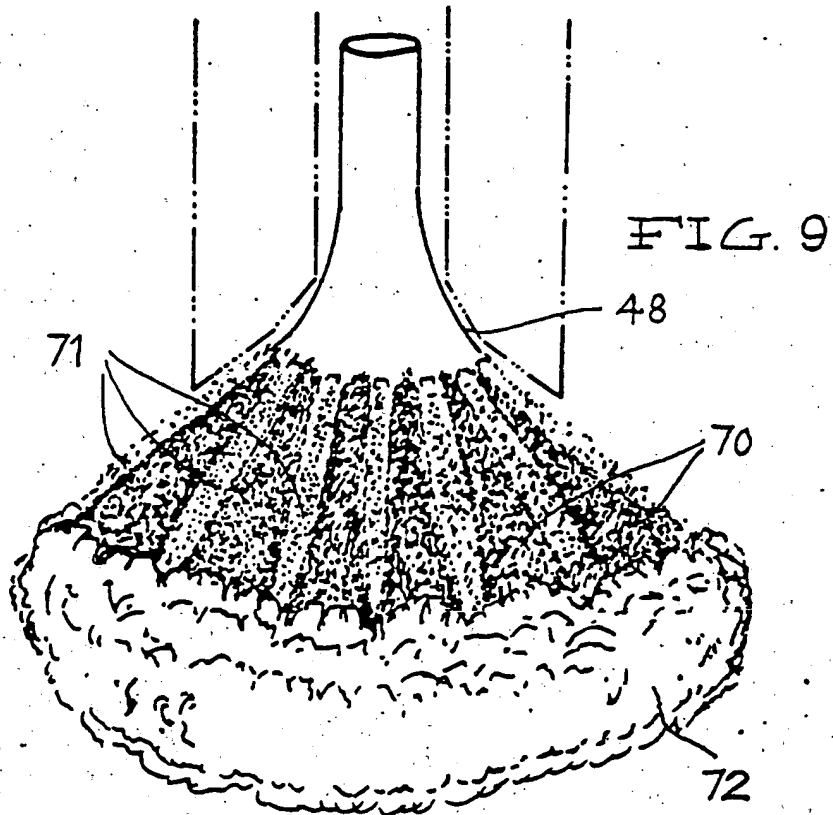


FIG. 8.

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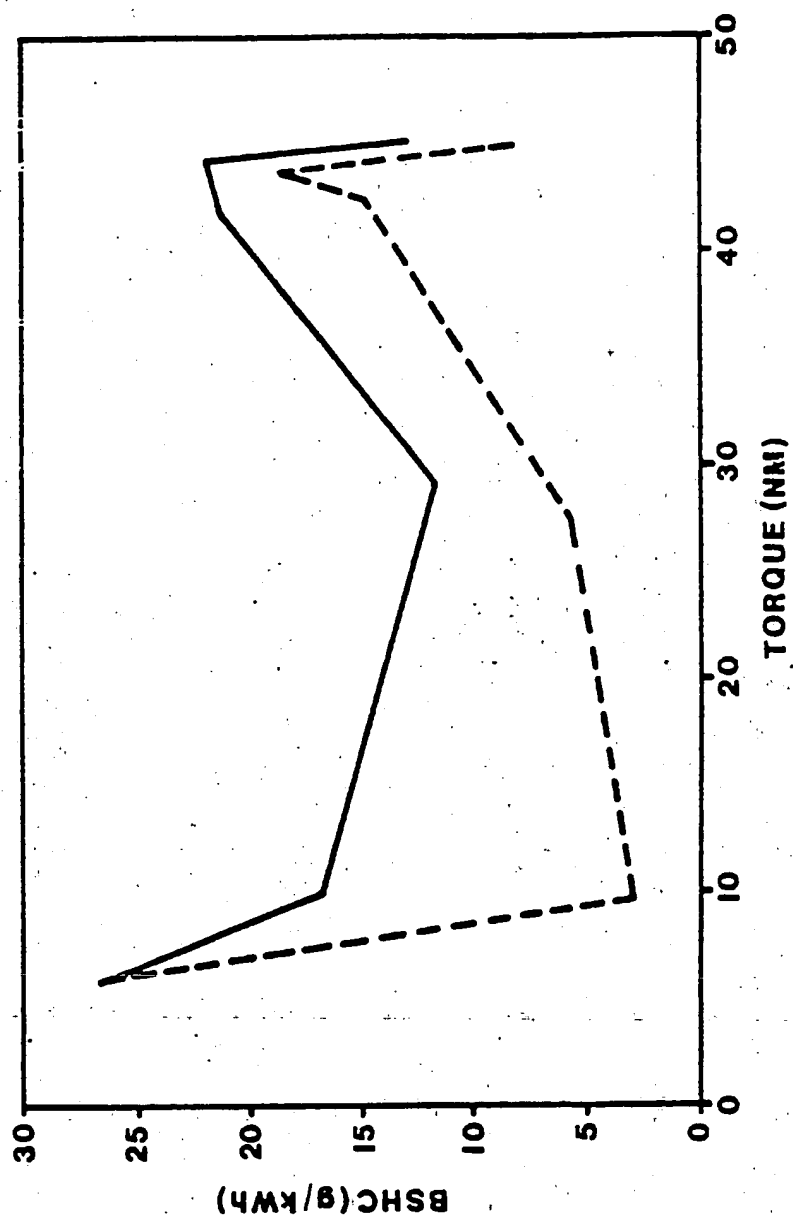
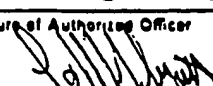


FIG. 11.

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 86/00201

I. CLASSIFICATION OF SUBJECT MATTER (If separate classification symbols apply, indicate them) According to International Patent Classification (IPC) or to both National Classification and IPC Int. Cl. ⁴ F02M 61/04, 61/08, 61/18, 67/12, 69/04		
II. FIELDS SEARCHED Minimum Documentation Searched? Classification System Classification Symbols IPC F02M 61/04, 61/08, 61/18, 67/12, 69/04 Documentation Searched other than Minimum Documentation to the extent that such documents are included in the Fields Searched? AU: IPC as above; Australian Classification 66.7		
III. DOCUMENTS CONSIDERED TO BE RELEVANT*		
Category*	Citation of Document, ** with indication, where appropriate, of the relevant passages**	Relevant to Claim No. 1
X,Y	DE,C, 916365 (DAIMLER BENZ AG) 9 August 1954 (09.08.54)	(1,3,10,15,18)
Y	DE,C, 723801 (AKTIENGESELLSCHAFT ADOLPH SAURER) 11 August 1942 (11.08.42)	(1,3,10,15,18, 24,35,39)
Y	GB,A, 1219826 (CATERPILLAR TRACTOR CO.) 20 January 1971 (20.01.71)	(1,3,10,15,18)
Y	GB,A, 2057057 (NISSAN MOTOR COMPANY LIMITED) 25 March 1981 (25.03.81)	(1,3,10,15,18)
Y	GB,A, 2088950 (LUCAS INDUSTRIES LIMITED) 16 June 1982 (16.06.82)	(1,3,10,15,18, 24,35,39)
Y	GB,A, 2097471 (LUCAS INDUSTRIES PLC) 3 November 1982 (03.11.82)	(1,3,10,15,18)
Y	GB,A, 2143582 (LUCAS INDUSTRIES PUBLIC LIMITED COMPANY (UNITED KINGDOM)) 13 February 1985 (13.02.85)	(1,3,10,15,18)
Y	DE,C, 483935 (ACRO AG) 3 October 1929 (03.10.29)	(35)
A	US,A, 2213928 (GOLD et al) 3 September 1940 (03.09.40)	
Y,P	WO,A, 86/00668 (LAMPARD) 30 January 1986 (30.01.86)	(35)
* Spec. of categories of cited documents: 10 "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step "Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "Z" document member of the same patent family		
IV. CERTIFICATION		
Date of the Actual Completion of the International Search 24 September 1986 (24.09.86)		Date of Mailing of this International Search Report (06.11.86) 6 NOVEMBER 1986
International Searching Authority Australian Patent Office		Signature of Authorizing Officer  C.M. WYATT

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 86/00201

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Members					
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GB	2057057	DE	3031298	FR	2463861		
GB	2088950	AR	224980	BR	8107856	DE	3147847
		FR	2495695	JP	57122156	ZA	8107406
GB	2143582	DE	3425493	ES	534317	FR	2549150
		JP	60036774	US	4549696		
WO	86/00668	AU	45484/85				

END OF ANNEX